AIR–SEA INTERACTION AND REMOTE SENSING

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This status report concerns our research conducted under grant NAGW–1322 to the University of Washington from the Oceanic Processes Branch of the National Aeronautics and Space Administration for the period between December 1, 1991 and November 30, 1992. The proposed work consisted of two parts and our progress in each one up to the present time is summarized below.

A. EXPERIMENT ON R/P FLIP

The first part of the proposed research was a joint effort between our group and Drs. Andrew Jessup and Peter Dahl of the Applied Physics Laboratory (APL), University of Washington. Our own research goal is to investigate the relation between the air–sea exchange processes and the sea state over the open ocean and to compare these findings with our previous results obtained over a small body of water namely, Lake Washington. The goals of the APL researchers are to study (*i*) the infrared sea surface temperature (SST) signature of breaking waves and surface slicks (by A. Jessup under a NASA grant) and, (*ii*) microwave and acoustic scattering from water surface (by P. Dahl and A. Jessup with support from an ONR–ARL program). The task of our group in this joint effort is to conduct measurements of surface fluxes (of momentum, sensible heat and water vapor) and atmospheric radiation (longwave and shortwave) to achieve our research goal as well as to provide crucial complementary data for the APL studies.

The field experiment took place between January 12 and February 2, 1992, initially about 100 nautical miles off the coast of San Diego (Figure 1) aboard the research platform FLIP (Floating Instrument Platform). The location had been chosen by the APL group due to the high probability of encountering strong winds and high seas this time of the year in this area. Contrary to this expectation, during most of the experimental period the winds were exceptionally light (5 m/s or less). Wind speeds of 10 to 12 m/s were encountered during the set up phase (before January 17) and during a frontal passage on January 31 (Figure 2). Consequently, R/P FLIP drifted in a westerly path (another unexpected situation) and was about 400 miles offshore on February 2. These conditions may have been caused by the El Niño event which was at full bloom during January, 1992. Air and water temperatures and relative humidity during the experimental period are shown in Figure 3.

Our instrumentation was located at the tip of the 20 m port boom approximately 11 m above mean water level (see Plate 1: the K–Gill twin propeller–vane anemometer; fine–wire thermocouple psychrometer and Lyman–Alpha hygrometer inside a black cylindrical protective housing (spray–flinger); slow–response Pt–1000 wet and dry bulb temperature sensors with radiation shields; two solar and one terrestrial radiation sensors. The ship in the background is the R/V DE STEIGUER.) The times corresponding to the data sets with wind speeds exceeding 3 m/s and recorded through our data acquisition system are indicated in Table 1. Each run is 2 hours long. These data sets also include the signals relating to the motions of the platform as well as some of APL's signals such as wind speed, wind direction, wave height and SST. All signals including ours and APL's were also recorded on APL's data acquisition systems **continuously throughout the experiment** and are available to us.

Original plans of the APL group to purchase a sonic anemometer was not realized. Therefore, the surface flux calculations will be based on the measurements by the K–Gill anemometer. The K–Gill anemometer used on R/P FLIP differs from that described by Ataktürk and Katsaros (1989) in the sense that it is equipped with two level sensors measuring the pitch and roll of the instrument. It was developed for use on a spar buoy in the SWADE (Surface Wave Dynamics Experiment) program and was later used on a SWATH (Small Water plane Area Twin–Hull) ship during SWADE (Katsaros, Donelan and Drennen, 1992). A similar unit has also been successfully used to measure the wind stress for winds above 6–7 m/s from a discus buoy (Anctil and Donelan, 1991) during SWADE. However, extreme caution must be used in dealing with light winds (as in our case) and large swell when propellers may stall or even rotate in the reverse direction.

At present, efforts are under way to correct the wind measurements for the motions of the platform. Once this is satisfactorily achieved, together with the data from thermocouple system and a SST sensor, we can easily determine the surface fluxes of momentum, sensible heat and latent heat hence, the atmospheric stratification parameter, z/L where z is the measurement height and L is the Obukhov length. The technique of calculating these quantities is described by Ataktürk (1991) in detail. (This reference has been presented to NASA as a technical report.) Availability of the directly determined fluxes will reduce the uncertainties in the interpretation of the data collected by other participants.

We will soon process the data on short and longwave irradiances to calculate the net radiative heating or cooling of the sea. In our approach, we use a well proven model for albedo (Payne, 1972) and the Stefan–Bolzmann law for longwave emissions to provide the exitance terms. See Katsaros (1990) for details of this procedure, which we have carried out in numerous experiments including the HEXOS (Humidity Exchange Over the Sea) Main Experiment, HEXMAX. The information on the net radiative heat flux will aid in interpretation of the observed SST variability.

B. EXPERIMENT ON LAKE WASHINGTON

The second part of the proposed research involves measurements of surface fluxes and the directional wave spectrum on Lake Washington. Our efforts are focused on the relationships between wind stress, surface roughness, directional wave spectrum and wave breaking. The results from part A (open ocean) and part **B** (limited fetch) will be compared to investigate the dependence of these relationships on the spectral width and angular variability of surface waves. Implications of the findings for ocean–atmosphere coupling and remote sensing will be sought.

Field experiments at our tower on Lake Washington include

- measurements of surface fluxes of momentum, sensible heat and water vapor,
- measurements of surface wave heights using an array of 8 wire wave staffs,
- video recordings of the water surface.

Surface flux measurements are quite similar to those conducted on R/P FLIP except that the winds will also be measured using 3–axis sonic anemometers. Of the three sonic anemometers, one is a low–power–consumption instrument recently purchased under an NSF grant and used on the buoy MENTOR during SOFIA–ASTEX (Surface de L'Ocean les Flux et leurs Interactions avec L'Atmosphere [Surface of the Ocean, Fluxes and Interactions with the Atmosphere] – Atlantic Stratocumulus Transition Experiment) in Azores–Maderia region in June–July, 1992. The other two (borrowed on long term basis) are identical and older designs. Proper operations of these older models were tested at our field site against the K–Gill anemometer during July, 1992. With these fast response sonic anemometers together with Lyman–Alpha hygrometers (we also have three of them now), we will improve our measurements in particular during stable atmospheric stratification conditions when contributions to total flux by the small eddies become more significant.

Complete description of a wave field requires distribution of the wave energy with respect to all frequencies (wavenumbers) over all possible directions. Our previous measurements on Lake Washington have provided information on the frequency distribution, but not on the angular spreading of wave components. (Although, from our qualitative observations we know that the waves on Lake Washington have a narrower angular spread than those on larger bodies of water due to channel like shape of the lake.) We acquired an 8–element array of capacitance wave wires to determine the directional wavenumber spectrum of the waves at our site. (The sensors are manufactured by Richard Brancker Research, Ltd., Ottawa, Canada. Dr. M.A. Donelan, Canada Centre for Inland Water, Burlington, Ontario, provided the electronics for the array.) Construction of the support structure made of aluminum is complete (see, Plate 2 and Figure 4). The array geometry was designed such that six wires are located in the center and at the corners of a pentagon. Two additional wires and the central one form a triangle with a separation of 1.5 cm between each pair. These three wires in the middle will be used to measure the surface slope. The calibration and test runs are planned for the fall of 1992. Dr. Mark A. Donelan who designed and used this type of arrays also promised us help with the data analysis techniques. Hence, obtaining the directional wavenumber spectrum should soon be realized.

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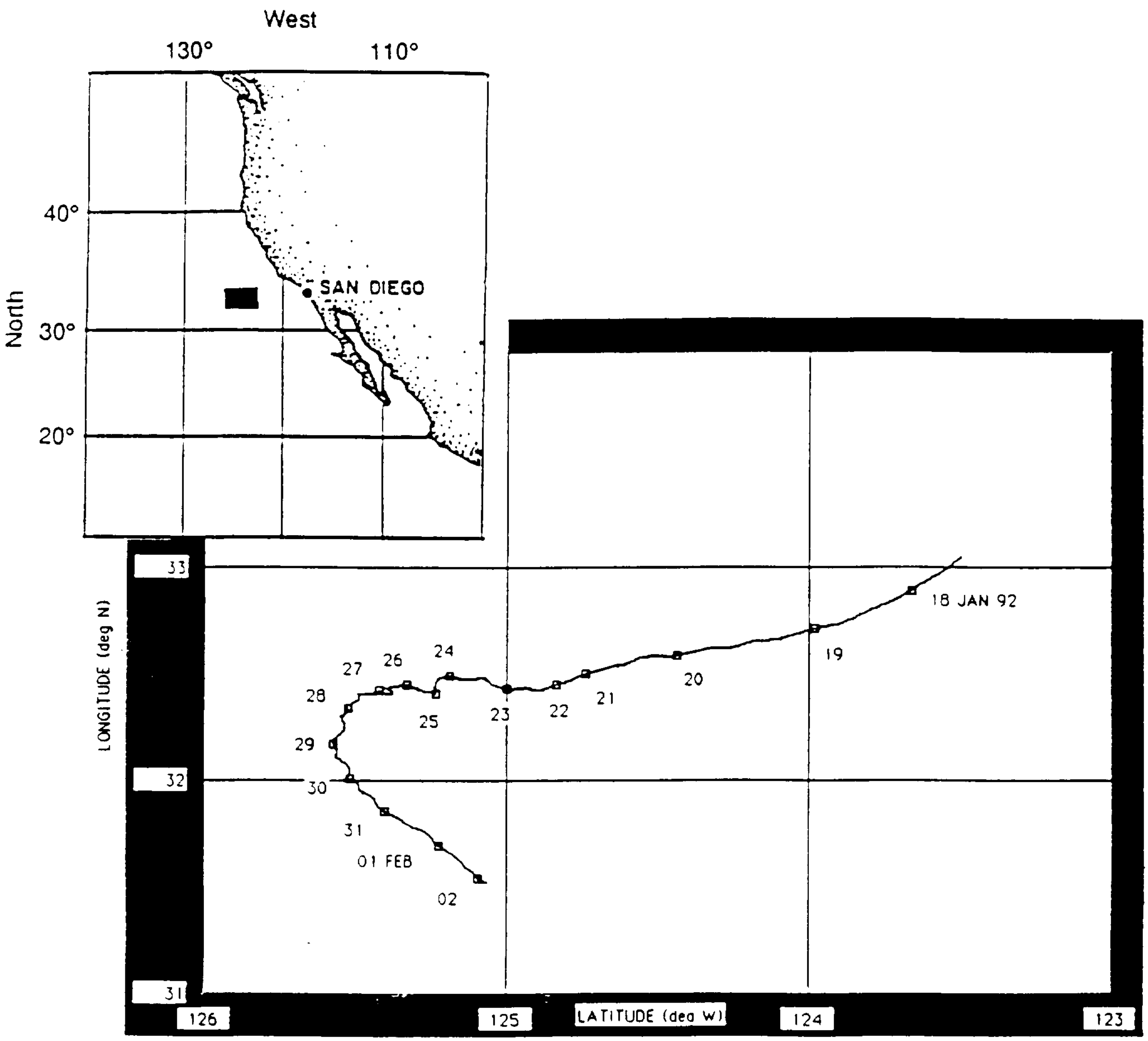


Figure 1. R/P *FLIP* drift track from GPS navigation system. Locations at 0000 hours local time are indicated along the track.

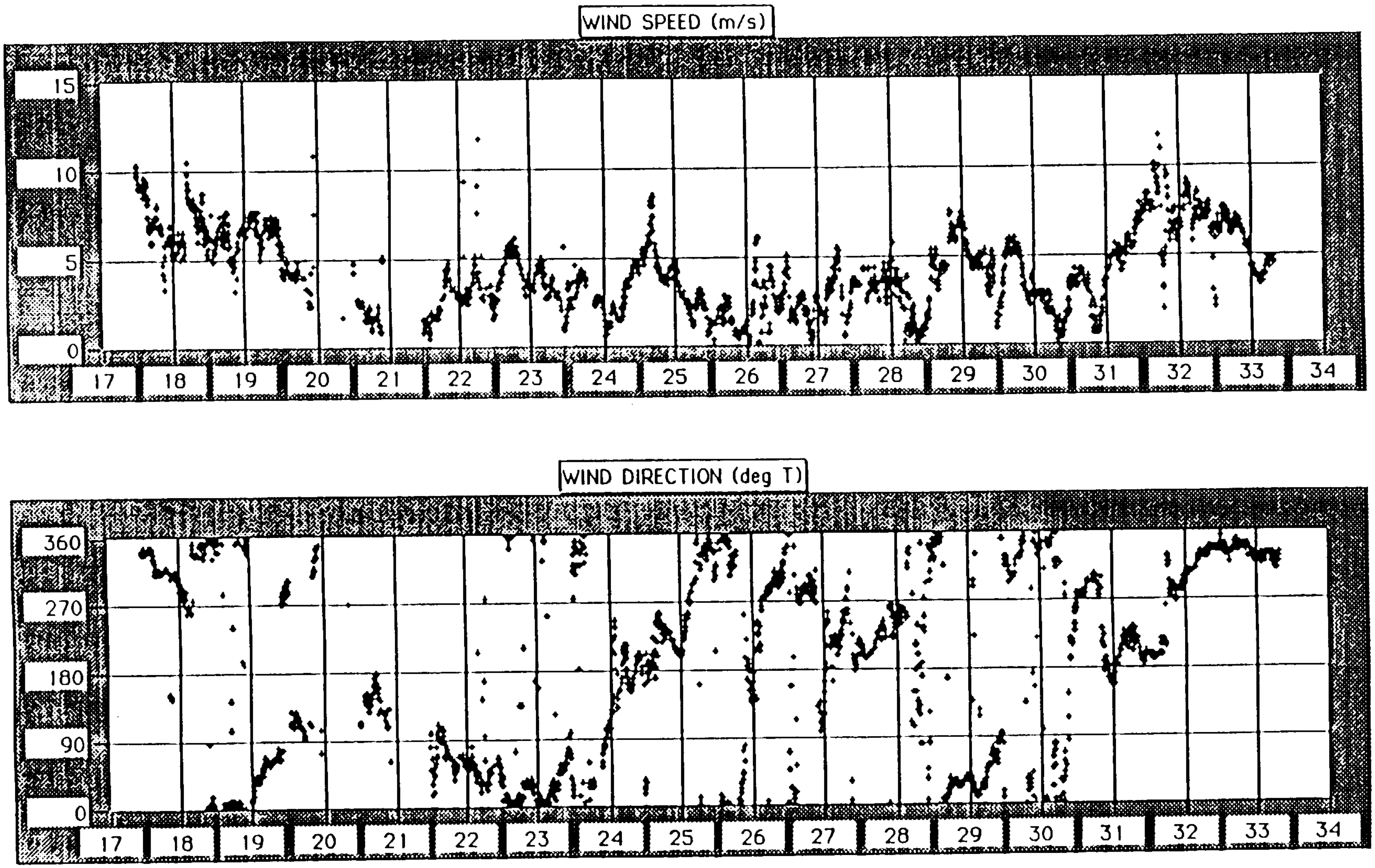


Figure 2. Time series of wind speed and direction for the duration of the experiment. The horizontal axis is in Year Days (1 Jan is Day 1). These data contain a few outliers due to interference from RF radio transmissions.

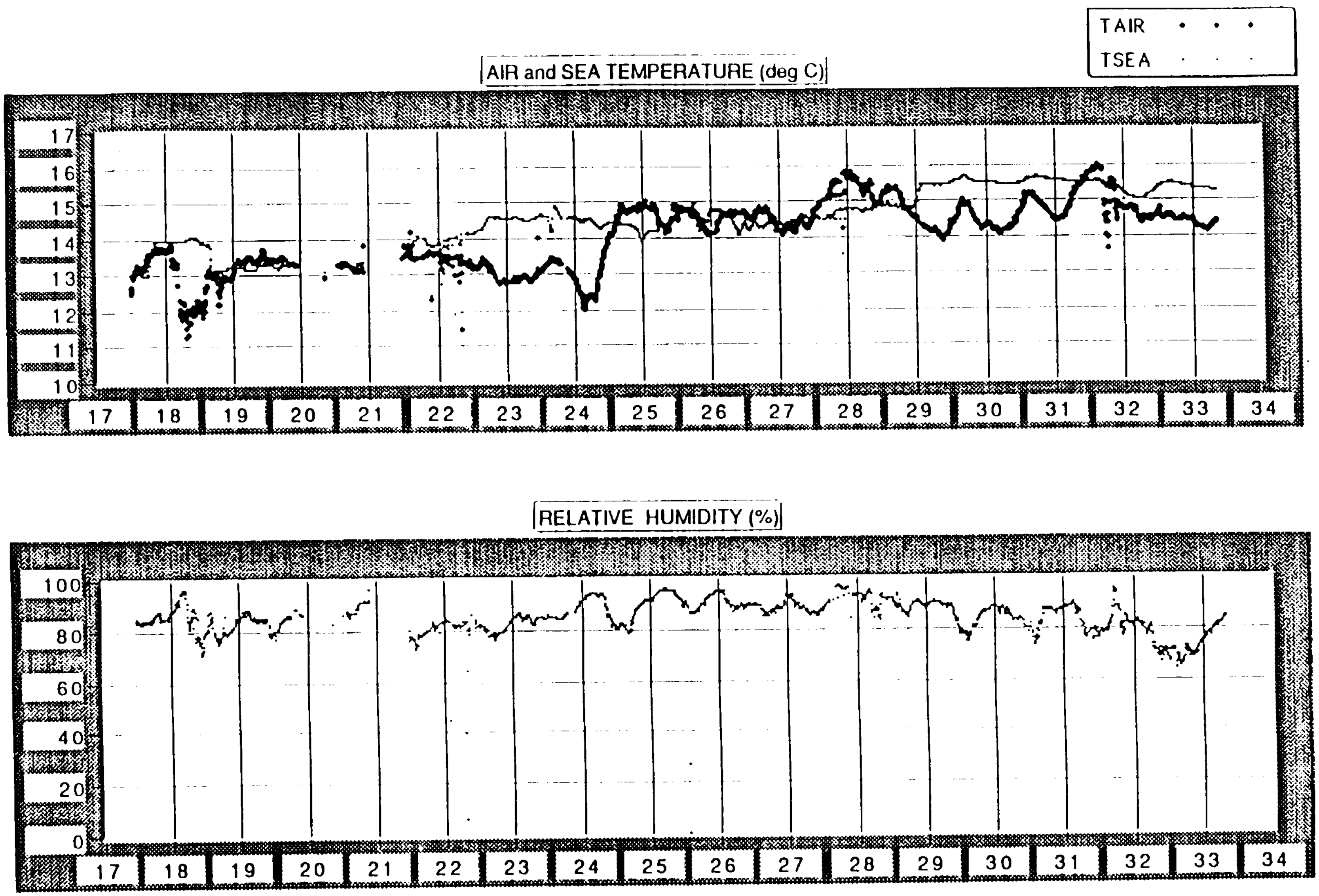
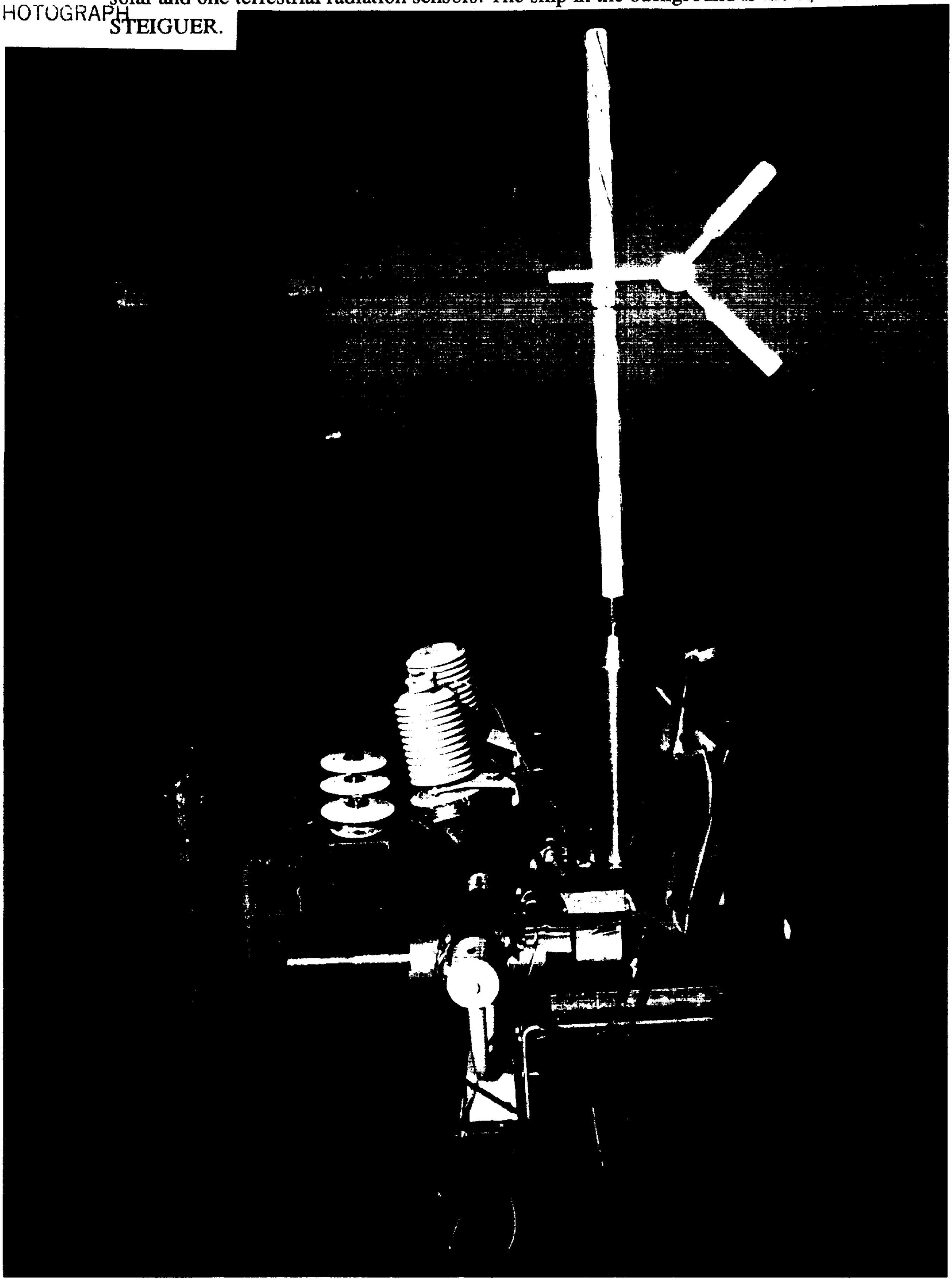


Figure 3. Time series of air temperature, sea temperature, and relative humidity for the duration of the experiment. The horizontal axis is in Year Days (1 Jan is Day 1). These data contain a few outliers due to interference from RF radio transmissions.

Plate 1. Instrumentation used by the University of Washington group on R/P FLIP consisted of the K–Gill twin propeller–vane anemometer; fine–wire thermocouple psychrometer and Lyman–Alpha hygrometer inside a black cylindrical protective housing (spray–flinger); slow–response Pt–1000 wet and dry bulb temperature sensors with radiation shields; two solar and one terrestrial radiation sensors. The ship in the background is the R/V DE STEIGUER.



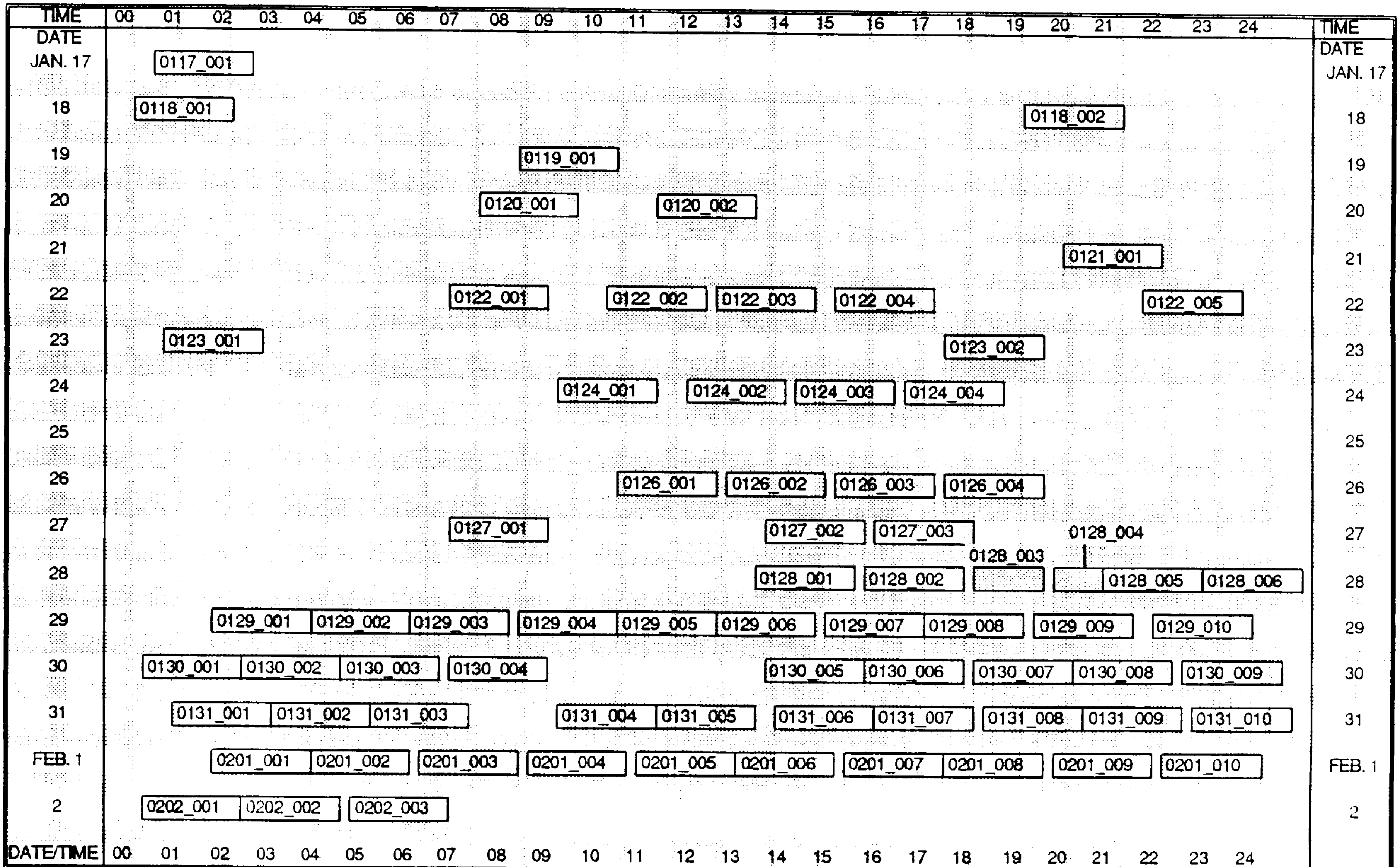
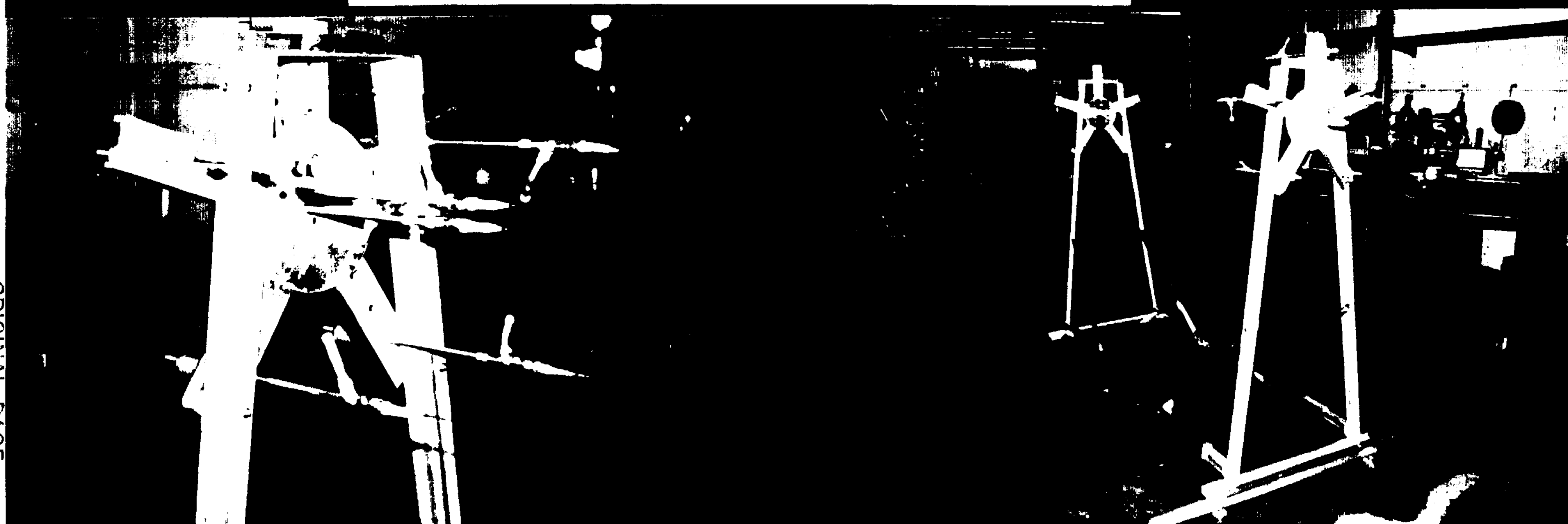


Table 1. Time table of the data sets recorded on the HP data acquisition system of the University of Washington. Each run is 2 hours long (except runs 0128_003 and 0128_004 which are 1.5 and 1 hour long, respectively).

Plate 2. Photographs of supporting structure for the 8–wire wave staff.



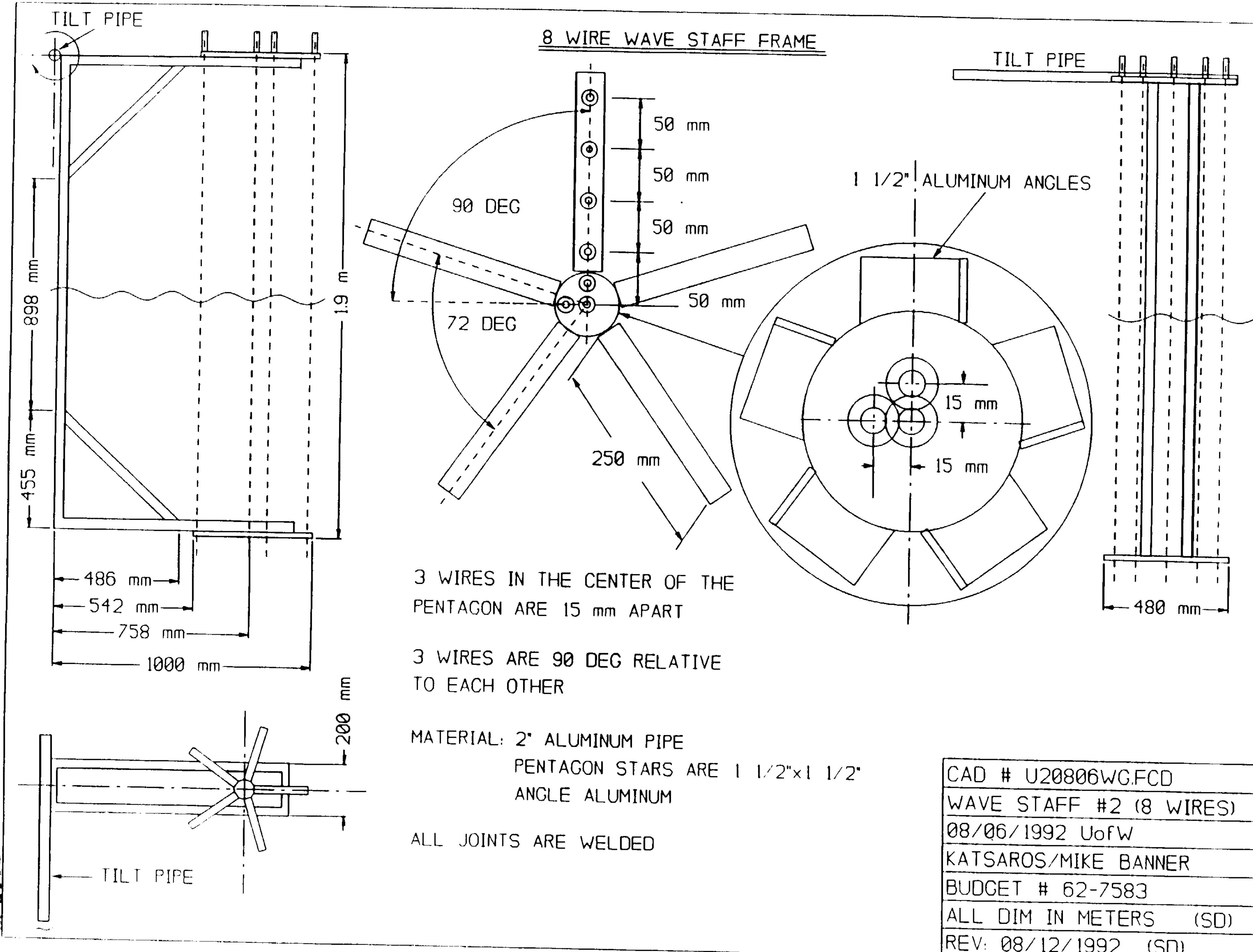


Figure 4. Technical drawing of supporting structure for the 8 wire wave staff